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ABSTRACT

A literature review synthesized the qualitative research from science education that described students' cognitive processes in conceptual change and the related effects of context. Studies were located by manual and on-line searches of more than 15 data bases to retrieve the published, unpublished, and fugitive research. The actual case studies that were located centered around themes of metacognition, motivation, and collaboration. Like the case studies, much of the research using interviews and observations focused on students' constructs and how those constructs were manifested in the classroom. Pursuing questions like the ones raised in studies from science education (the influences of students' views of science, their folk language, their interaction patterns in collaborative groups, and their texts, instruction and curriculum) may help to identify the influences that affect students' conceptual change. Researchers in reading education should heed the call from science education researchers to conduct studies that include more multicultural samples and more longitudinal observations of students across grades. Expanding the focus and design of such studies in these ways offers the potential for developing effective instruction and for creating texts that are sensitive to individuals. Contains 27 references.) (RS)

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from Science Education

RUNNING HEAD: Critical Review

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Critical Review of Qualitative Research on Conceptual Change in Science Education

Meta-analysis of instructional interventions to promote conceptual change in science from reading education and science education (Guzzetti, Snyder, Glass & Gamas, 1993) revealed the need to examine extant naturalistic research and to create future studies from a new paradigm. Our first decade of research on conceptual change from reading education consisted of empirical investigations, although some of our studies used naturalistic techniques, like interviews (Guzzetti, 1990) or on-line observations of students (Alvermann & Hynd, 1987).

This quantitative research enabled us to identify particular instructional strategies that consistently showed high average effects, like refutational text (Guzzetti, Snyder, Glass & Gamas, 1993). Nevertheless, several questions could not be addressed through quantitative research. First, experimental research did not allow us to describe how or why particular strategies produce conceptual change. Strike and Posner (1992) have wondered what conceptual processes a student experiences during instruction. Second, empirical research has provided only average effects for groups of students; we still do not know how individual student characteristics, like age, culture, ethnicity, and gender enhance or interfere with students' abilities to change their thinking. Bloom (1992) suggested that investigations into students' sociocultural contexts, as well as their attitudes, interests and motivation might shed some light on these questions. Pintrich, Marx and Boyle (in press), have called for studies of the

influence of students beliefs' about themselves as learners, and their roles as individuals in a learning community.

Purpose

I conducted this review to synthesize the qualitative research from science education that described students' cognitive processes in conceptual change and the related effects of context. By examining the qualitative research from science education, I hoped to find reports of the influences of cultural, social and contextual conditions on the process of conceptual change. Perhaps these descriptions might lead us in reading education to design new instructional approaches and texts that would be more sensitive to individuals. I also anticipated discovering recommendations for future inquiry that might assist us in reading education to design our second generation of research in conceptual change.

Procedures

Studies were located by manual and on-line searches of more than 15 data bases to retrieve the published, unpublished and fugitive research. Retrieval of the most recent literature was accomplished by perusal of conference programs from professional meetings. Despite these extensive search processes, this review is not all-inclusive of the extant qualitative research.

Case Study Research

The actual case studies (i.e., complete studies of a bounded system as described by Stake and Easley, 1978) that were located centered around themes of metacognition, motivation and collaboration. One such study was conducted by Hennessey and

Beeth (1993), and was based on the premise that metacognition is necessary for conceptual change learning. This study reported a three-year instructional intervention in grades 1-6, Project META (Metacognitive Enhancing Teaching Activities). Instruction was designed to explicitly enhance students' metacognition by enabling students to consider the implications of their reflective thoughts. The project aimed to describe the impact of this kind of instruction on the formation of students' ideas.

Students were exposed to the technical language of conceptual change theory, i.e., that conceptions should be considered on the basis of their intelligibility, plausibility and fruitfulness. Individuals worked in small groups and whole-class discussions to build a consensus about a set of descriptors that for them best exemplified the meaning of each of these technical terms. Students were then given application exercises to determine if they had developed the concepts of intelligibility, plausibility and fruitfulness, if they could sufficiently differentiate between these terms, and if they could apply them to their own conceptions of particular topics. Exercises were written extracts taken from the professional literature, doctoral dissertations, sixth grade students' writings, and the students' own writings that described each of these three terms. Students were asked to comment on whether the extracts were intelligible, plausible and fruitful to them; they were also asked to provide their reasons why or why not. A final set of descriptors for each term was arrived at by consensus. Following this phase, students in grades four through six focused on applying the technical language to

four through six focused on applying the technical language to their conceptions of science content. Students were audiotaped and videotaped extensively and regularly.

Data analysis yielded five types of metacognitive reflections. These included reflections that explicitly referred to students' personal constructs or knowledge claims; reflections that explicitly referred to the reasoning behind students' constructs or knowledge claims; reflections that explicitly considered the implications or limitations inherent in the students' constructs or knowledge claims; reflections that explicitly referred to the status of students' conceptions; and reflections that explicitly referred to the components of students' conceptual ecologies. An illustration of the latter type of reflection was provided by the following excerpt from a discussion (pp. 25-26):

"Melinda: Everybody seems to be talking about whether the pictures were intelligible or not so I'll start with intelligible too. Well, their intelligible to me I can understand what the pictures are trying to say about atoms, but they're not plausible to me because I cannot believe from anything that I have done, or anything than I have seen anybody do, that atoms are dead but they can still move. That part is intelligible but not plausible. The pictures are intelligible alright but not the ideas behind the pictures. I cannot understand how molecules can do that [move] if they are dead."

Based on data like these, Hennessey and Beeth (1993) reached four conclusions. First, they noted that students can provide extensive and varied evidence of their metacognitive abilities. Second, they stated that differences exist in the types of metacognitive statements produced by students instructed in the

technical language of conceptual change. Third, they concluded that analyses of these statements provide insight into the reasoning and justification behind students' ideas and the components of their conceptual ecologies. Finally, the authors advised that to promote conceptual change, it is necessary for students to engage continually in metacognition.

It is difficult to evaluate the merits of this case study and its conclusions because of the vague description of the study's design, particularly for data collection and analysis. The reader is not informed of the extent and duration of data collection or who collected the data (from the spelling and grammatical errors in the sample transcription excerpt, it appears as if students did the transcriptions of the videos and audiotapes). No mention is made of any formal procedure for data analysis, either. The brief excerpts from videotapes or audiotapes do not convince the reader that they illustrate the propositions attributed to them. For example, Melinda's statement that the photos (of what we are not informed) are intelligible, but not plausible to her, is not particularly revealing of her conceptual ecology (related ideas) regarding matter. She stated that she believed molecules move, but that she also thought molecules were dead, and that these two ideas were incompatible. Why, however, would she consider this incongruity intelligible, but not plausible? The authors do not inform the reader how the students defined each of these terms.

Despite its flaws, this case study suggests direction for future inquiry in reading education. A study might be designed in

which articulate students who hold alternative conceptions are followed longitudinally. Students might be interviewed and observed in activity focused on the scientific concepts for which they hold alternative conceptions to examine how their conceptions change. Students might also be asked to think aloud when reading refutational text and to describe their reactions.

A related study examined motivation with 12 students from two sixth-grade science classrooms (Lee, 1991). This inquiry was also conducted within the context of a conceptual change approach, using instructional materials and curriculum developed by the researcher. Students were described as ethnically mixed and representative of high, medium and low achievement levels. Focused observations were conducted of students' task engagement to determine their levels of motivation. Individuals were observed on 10-12 occasions of about 10-20 minutes each. Six patterns of classroom motivation were identified, indicating different goals and levels of task engagement in science activity. These included: 1) intrinsically motivated to learn science, 2) motivated to learn science, 3) intrinsically motivated (but inconsistent), 4) not motivated to learn science - task completion, and 5) not motivated to learn science - task avoidance. Findings demonstrated a lack of motivation for various reasons, including inconsistent interest across tasks, determination to avoid mental effort, apathy and indifference to learning science, and disruptive behavior and discipline problems due to negative attitudes. Lee concluded that, "teachers need to

be aware of the various reasons for students' lack of motivation to learn so that they can provide assistance for the specific needs of individual students" (pp. 26-27).

Explanations of how teachers can use this knowledge to provide individual assistance within a conceptual change approach has not been offered. The need to identify students' motivation as an influence in conceptual change has also been seen as important by other researchers, however. Like Hennessey and Beeth (1993), White (1993) emphasizes the importance of metacognition by stating that for conceptual change to occur, students must recognize their beliefs, consider their worth, and compare them with the new information. Hence, metacognition is an essential element of conceptual change. White suggests that in addition to Flavell's (1976) three aspects of metacognition (knowledge about thought processes, awareness of one's own use of them, and their purposeful control) a vital fourth exists -- willingness to exercise that control. The first three aspects of metacognition can be taught, and are considered vital to securing the fourth.

Case studies in reading education might follow this directive by examining the influences of students' metacognitive ability on their motivation and conceptual change. This focus seems useful in light of Hewson and Thorley's (1989) advice to note that changes in students' conceptions cannot be derived from details of the content of the conception itself, but can only come from students' comments about the conception -- "dissatisfaction,

intelligibility, plausibility and fruitfulness all refer to the learner's viewpoint" (p. 550).

A third case study conducted within the context of an intervention was one in which teachers became action researchers. This study was described in several manuscripts (Roth & Bowen, 1993; Roth & Bowen, 1993b; Roth & Bowen, in press). The purpose of the study was to determine how students learn and change their understandings within an open-inquiry setting. The teacher and other adults who interacted with the students used the metaphor of graduate research advisor to describe their role. Adults emphasized engagement in practice by modeling expertise in use, coaching, or scaffolding students' initial attempts in a new skill on a need-to-know basis, and served as advisors in the students' independent projects.

The authors refer to recommendations from reports on science and mathematics education (American Association for the Advancement of Science, 1989; National Council of the Teachers of Mathematics, 1989) to enculturate students into authentic practice. They note that these practices are "fundamentally collaborative in nature" (p. 3), and they cite the benefits of cooperative learning on achievement. As a result, this study was also designed to address questions about "the mediational and interactional processes which lead to the benefits of cooperative learning, the cognitive processes that are evoked by peer collaboration, and the students' beliefs and task conceptualizations in collaborative groups" (p.3).

Data were collected in a private school with eighth-grade students (predominantly boys) from middle, upper middle and upper class families. Students experimented in groups of self-selected pairs throughout the year; at times pairs were asked to form a triad with another individual for discussions of their findings. Data collection focused on a 10 week ecological study of the campus in which students were to study the interrelations between abiotic and biotic features in a small plot of land called an ecozone. Data were gathered from audiotapes and videotapes, students' field notebooks and laboratory reports, students' answers to specially designed word problems, and the researcher's field and reflective notes.

In light of the research on collaborative groups from reading education, this study is most interesting for its emphasis on and analysis of language in collaborative dialogue. For example, the researchers concluded that:

At the level of the conversation, the above excerpt made evident the recurrent contingency who should talk now; the fact that someone continues is an outcome coordinately achieved out of that contingency (Schegloff, 1982). The students took their turns at contributing to the emerging construction or relinquished their turn to allow another to complete this construction. Relinquishing one's turn in the context of another's contribution is in itself part of the collaborative achievement" (p. 11).

Roth and Bowen (1993) conclude that as students increased their familiarity with the setting, their discourses increasingly included appropriately scientific concepts. Students could test their emerging constructions through collaborative conversation and negotiation. The authors stated that, "It is through

interactions, negotiations of meaning, interactive problem-solving and collaborative constructions that students learn, rather than through hands-on activities per se" (p. 15).

Despite their positive reports of the effects of interactive discussions, the authors did report at least one instance captured in a transcription in which they conceded that arguments and counterarguments were used by students to convince each other of their positions. The "better" or more convincing argument was the one students accepted. The authors dismissed this as a part of the collaborative nature of inquiry. Recent studies in reading education (Marshall, 1992; Hynd, McWhorter, Phares & Suttles, 1991) and instructional design (Snyder, 1993) have shown, however, that students in collaborative groups convince each other of their misconceptions. The dominant individual who has the most persuasive argument tends to "win" the disagreement. Those of us in reading education conducting research in the effects of collaboration on conceptual change would agree that the role of the teacher in such a setting would be crucial to facilitating conceptual change in the direction of the scientific conception. Studies by Alvermann and Hynd (1989) and Guzzetti and Kowalinski (1992) showed that small group discussion was only effective in producing conceptual change when interactive between teacher and students and students and students, focused around a central question or statement, and requiring supportive evidence from text.

These case studies in science education share a commonality in focus by emphasizing language. Researchers in reading education focusing on conceptual change can provide thick descriptions and analyses of language between students and teacher and among students when engaged in instructional activity. In doing so, we should be aware of Tull's (1992) observation that children's explanations of concepts may appear naive from the scientific viewpoint, but often the child's explanation is consistent with the viewpoint of the adult lay person, and represents a common sense framework. That framework is influenced by folk language, rather than by scientific language, which is not surprising since folk language comprises the majority of terms used in our language. Familiarity with and use of these folk terms may impede conceptual change when the folk term is inadequate, imprecise or incorrect in describing a phenomenon or at variance with the scientific term. Terms represent concepts, and Tull (1992) reminds us that a concept is an abstraction or a generalization; communication of those concepts depends on how well students can construe the construct system of others.

Interview and Observation Research

Like the case studies, much of the research using interviews and observations focused on students' constructs and how those constructs were manifested in the classroom. Linn and Songer (1992) focused on middle school students' ideas about the nature of science. These researchers noted that the stance students take

toward science lends insight into the roles they assume in rationale and critical thinking and provides insight into their reasonings about science. They asked students questions like, "Will the science principles in textbooks always be true? Explain your answer. Can scientists look at the same experiment and reach different conclusions? Explain. To verify their findings, do scientist compare their results to those of others? Explain" (pp. 13-14). Responses indicating that scientific ideas develop were scored as dynamic; those indicating that ideas do not change were scored as static. Linn and Songer found that some students view science as static, as a collection of established ideas to be memorized, while others view science as dynamic, as ideas to be understood. Students with dynamic views were more likely to acquire integrated understandings of scientific ideas.

These researchers posit that students acquire their static views of science from science texts and curriculum, particularly from lectures and science texts that communicate a view of science as established by authority rather than resulting from logical analysis. They cite Reif and Larkin (1991) who note that science textbooks hide the details of scientific discovery, do not communicate that scientists grapple with conflicting observations, and provide a model of scientific behavior incompatible with research science. Tull (1991) agrees, stating that textbooks have placed an emphasis on science as a body of knowledge rather than as a way of thinking, and contain false or misleading concepts. Teachers who use texts may adopt an

authoritarian lecture mode that discourages debate and discussion, a mode often adopted in peer discussions when students take turns asserting opposing views.

Although teachers' practices may influence students' views of science, researchers have found that teachers' views do not influence their students' views of science (Lederman & Druger, 1985). Observations of 18 high school biology classrooms were conducted to compare teachers' and students' conceptions of science. The data revealed that teachers did not pass on their conceptions of science to students. Observations revealed, however, that teachers' conceptions of science do not necessarily match their instruction.

In designing our studies, Dickie and Kato (1993) ask us to consider the learning environment, the teacher's style, the teacher's conceptualization of teaching, the types and effects of assessment, and the student's approaches to problem solving and beliefs about learning. These researchers interviewed 13 college students in honors physics and found that students saw themselves learning physics by solving problems and by struggling with the ideas on their own or in collaboration with others, rather than by merely listening to an exposition of ideas. These self-reported learning styles are congruent with constructivist theory that students actively create their own meanings.

Implications

Pursuing questions like the ones raised in these studies from science education (e.g., the influences of students' views of

science, their folk language, their interaction patterns in collaborative groups, and their texts, instruction and curriculum) may help to identify the influences that affect students conceptual change. In doing so, researchers in reading education should heed the call from science education researchers to conduct studies that include more multicultural samples and more longitudinal observations of students across grades (Cummings; Good & Peebles, 1993). Expanding the focus and design of our studies in these ways offers the potential for developing effective instruction and for creating texts that are sensitive to individuals.

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